SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS.

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[Dated: Solar Radiation Investigations Section, Washington, May 28, 1920.]

INSTRUMENTS AND EXPOSURES.

In the REVIEWS for August, 1914, **42**:474, and November, 1919, **47**:769, will be found illustrations and descriptions of the Callendar and the Marvin pyrheliometers, respectively. The former is employed by the Weather Bureau to obtain a continuous record of the total radiation received on a horizontal surface directly from the sun and diffusely from the sky. With the latter measurements are made of the intensity of direct solar radiation upon a surface normal to the incident solar rays whenever the sky about the sun is free from clouds. Both types are installed at Washington, D. C., Madison, Wis., and Lincoln, Nebr., and a Marvin pyrheliometer is installed at Santa Fe, N. Mex.

In the REVIEW for January, 1916, **44**:2, will be found a description of the exposures of the Marvin pyrheliometers at the above stations, which still apply, except for the modification in the exposure at Santa Fe noted in the REVIEW for January, 1917, **45**:2. Descriptions of the exposures of the Callendar pryheliometers at the different stations will be found in the REVIEW for January and April, 1916, **44**:4, 179 and 180, which still apply, except for the modification in the exposure at Madison, noted in the REVIEW for January, 1917, **45**:2.

Descriptions of the methods of obtaining and reducing radiation measurements will be found in the REVIEW for January and April, 1916, **44**:2, 4, 179, and 180, and for November, 1919, **47**:769. The Leeds and Northrup register used at Washington in connection with the Callendar pyrheliometer until September 27, 1919, was on that date replaced by a Callendar register. The determination of a new factor was necessary to reduce the records made by this register to heat units.

In the REVIEW for January, 1916, **44**:3, is given a description of the exposure of the Pickering polarimeter employed at Washington for measuring skylight polarization, and also an account of the manner in which the measurement is made. The exposure of a similar instrument in use at Madison is described in the REVIEW for January, 1917, **45**:2.

TABULATED DATA.

As explained in the REVIEW for January, 1916, **44**:2, measurements are made with the Marvin pyrheliometer when the sun has such zenith distances that the air mass is some multiple of 0.5, included between 1.0 and 5.5. Air mass 1.0, corresponding to zenithal sun, is never reached at any Weather Bureau station. On June 21, however, air masses of 1.03, 1.04, 1.05, and 1.06 are obtained at noon at Santa Fe, Washington, Lincoln, and Madison, respectively; while at noon on December 21 the corresponding air masses are 1.95, 2.15, 2.30, and 2.50.

In order that the data may be presented as compactly as possible, measurements are published only for air masses that are a multiple of 1.0. In addition, however, an extrapolation is made to obtain a value for zenithal sun, or air mass 1.0, whenever the character of the measurements will permit. If the extrapolation is for less than 0.25 air mass, the result is considered a measured value.

The following table gives the air mass corresponding to the noon position of the sun for each station on the 16th of each month, and indicate the amount of extra-

polation necessary to obtain a radiation intensity value for air mass 1.

Date.	Washington, D. C.	Madison, Wis.	Lincoln, Nebr.	Santa Fe, N. Mex.
Jan. 16	1.99	2.27	2.10	1.81
Feb. 16	1.59	1.76	1.66	1.49
Mar. 16	1.31	1.41	1.36	1.26
Apr. 16	1.14	1.19	1.16	1.11
May 16	1.06	1.09	1.08	1.05
June 16	1.04	1.06	1.05	1.03
July 16	1.05	1.08	1.06	1.04
Aug. 16	1.10	1.14	1.12	1.08
Sept. 16	1.24	1.31	1.27	1.19
Oct. 16	1.49	1.67	1.55	1.40
Nov. 16	1.87	2.12	1.97	1.72
Dec. 16	2.14	2.49	2.29	1.94

Table 1 gives the measured intensities, and the extrapolated values for air mass 1.0, obtained during the months January to April, 1920, at the four stations equipped with Marvin pyrheliometers. When any monthly mean is based upon less than three measurements it is inclosed in parentheses. The "Departures" are the difference between the means for the current month and the means of all the corresponding measurements obtained at the station since the beginning of observations—June, 1905, Washington; July, 1910, Madison; July, 1915, Lincoln; and October, 1912, Santa Fe. Values obtained by extrapolation for more than 0.25 air mass are not included in this latter mean. The values of e, the surface vapor pressure, are obtained from psychrometer readings made at the respective stations at 8 a. m., 75th meridian time, and noon, local mean solar time.

The departures in Table 1 indicate that in January radiation intensities were slightly above the average at Washington and below the average at the other three stations; in February they were slightly above the average at Santa Fe, and below at the other stations; in March, above the average at Washington and Santa Fe, below at Madison and Lincoln; in April, below the average at Lincoln, above at Washington and Madison. No measurements were obtained at Santa Fe during April on account of a defect in the measuring apparatus.

TABLE 1.—*Solar radiation intensities during January, 1920.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	8 a.m. 75th meridian time. e.	77.8° .0	75.7° 4.0	70.7° 3.0	60.0° 2.0	0.0° 1.0*	60.0° 2.0	70.7° 3.0	75.7° 4.0	77.8° 5.0	Noon Local mean solar time. e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 2	0.86		1.04								0.96
3	0.71	0.80	0.91	1.03							0.66
5	0.96		1.03	1.18	1.36	1.57		1.22	1.08	0.95	1.07
10	2.62		0.61	0.77							3.81
12	2.36	0.63	0.71	0.88	1.07	1.69	1.32	1.03			1.78
14	1.24	0.82	0.94		1.25	1.56		0.95	0.73		1.19
28	5.36							0.91	0.80	0.69	4.17
29	1.60				1.21			0.90			1.96
30	2.87			0.99	1.14		1.03	0.93			3.63
31	1.60	0.95	1.06	1.18	1.32	1.54	1.33	1.17	0.98	0.90	0.81
Means		0.80	0.90	1.00	1.22	1.52	1.02	0.90	0.85		
Departures		+0.05	+0.02	-0.01	±0.00		± .00	-0.02	+0.02	+0.07	

*Exptrapolation.

TABLE 1.—*Solar radiation intensities during January, 1920*—Continued.

MADISON, WIS.

Date	Sun's zenith distance →									
(Air mass) 8 a.m. e.	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 2 — 0.43							1.28	1.22		0.48
13 — 1.96		1.08	1.27		1.61		1.34	1.22		1.24
28 — 0.64	0.80	0.94	1.11	1.29	1.52					0.91
Means	(0.80)	(1.01)	(1.19)	(1.29)	(1.53)		(1.31)	(1.22)		
Departures		−0.14	−0.07	−0.06	−0.06		+0.07	+0.08		

LINCOLN, NEBR.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Jan. 2 — 1.78	1.05	1.11	1.24							1.32
9 — 1.19			1.10		1.44		1.14	0.98		2.49
12 — 3.30					1.54		1.05	0.94		3.99
14 — 3.45	0.74	0.88								4.37
15 — 3.99		0.89	1.17							4.37
17 — 2.16		1.09	1.24		1.58					2.36
21 — 1.19		0.99	1.16		1.54		1.18	1.04	0.91	2.06
27 — 1.37				1.19		1.19				1.24
29 — 2.62				1.25	1.49	1.28	1.10	0.94		6.02
Means	(0.90)	0.99	1.18	(1.22)	1.52	(1.24)	0.98	0.98	(0.91)	
Departures	−0.05	−0.06	±0.00	−0.14		−0.01	−0.09	−0.10	−0.09	

SANTA FE, N. MEX.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Jan. 9 — 0.86			1.30	1.47	1.67	1.40		1.14		1.52
12 — 1.88							1.23			2.62
14 — 2.26				1.38						2.87
24 — 3.00		1.18	1.34				1.33			3.30
27 — 2.87								1.23		3.45
28 — 3.15				1.46	1.58		1.34	1.23		3.63
29 — 2.16			1.34	1.52	1.72	1.49	1.41	1.23		2.74
30 — 3.15			1.41	1.50		1.50	1.38	1.27		2.62
Means		(1.18)	1.35	1.47	1.65	1.46	1.34	1.22		
Departures		−0.09	−0.03	−0.03		−0.01	±0.00	+0.01		

Solar radiation intensities during February, 1920.

WASHINGTON, D. C.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Feb. 13 — 5.16							1.01			4.75
14 — 3.99							1.01			4.75
16 — 0.79		0.66								0.79
17 — 1.52							1.24	1.03		1.96
19 — 2.74		0.77	1.05	1.28	1.56	1.26	1.01	0.78		1.52
20 — 1.68			0.82	1.04						1.88
25 — 1.78		0.77	0.92	1.10	1.31					1.78
26 — 1.52			0.72							1.37
Means		0.73	0.88	1.14	(1.44)	1.13	(1.02)	(0.78)		
Departures		−0.11	−0.13	−0.07		−0.09	+0.01	−0.07		

MADISON, WIS.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Feb. 19 — 0.71				1.15						0.51
25 — 1.37				1.29						1.32
26 — 0.58			1.21	1.38	1.62	1.38				0.86
Means			(1.21)	1.27	(1.62)	(1.38)				
Departures			−0.03	−0.11		−0.02				

LINCOLN, NEBR.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Feb. 7 — 3.81						1.20	0.94	0.84	0.82	5.16
9 — 3.81					1.32					3.30
10 — 3.30				1.33						3.63
14 — 0.91			1.26			1.27	1.12	0.97		0.96
16 — 1.78					1.46	1.24	1.05	0.94	0.80	3.00
17 — 3.00			1.25	1.37						3.45
19 — 4.57						1.23	1.00	0.88	0.77	4.57
26 — 1.02		1.17	1.26	1.44	1.64	1.35				1.45
27 — 2.36									C.89	3.00
Means		(1.17)	1.26	1.38	(1.55)	1.27	1.08	0.93	0.85	
Departures		+0.08	+0.02	−0.04		−0.08	−0.11	−0.10	−0.04	

TABLE 1.—*Solar radiation intensities during February, 1920*—Continued.

SANTA FE, N. MEX.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Feb. 14 — 2.26					1.64		1.29	1.18	1.01	2.87
15 — 1.96			1.40	1.54						2.26
16 — 3.00					1.68	1.44				3.99
17 — 2.87			1.47	1.57						3.81
18 — 2.49				1.52	1.62					2.62
26 — 2.26			1.34	1.51			1.37	1.23	1.12	2.36
27 — 2.87					1.72					2.87
Means			(1.37)	1.51	1.65	(1.44)	(1.33)	(1.20)	(1.06)	
Departures			+0.06	+0.04		+0.04	+0.03	+0.02	−0.01	

Solar radiation intensities during March, 1920.

WASHINGTON, D. C.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Mar. 1 — 1.45			1.04	1.28	1.56	1.23	0.97			2.16
2 — 3.15			0.53	0.81		0.94	0.64	0.46		2.74
3 — 3.30			0.74		1.34	1.06				4.37
6 — 1.12			1.13	1.36						1.24
8 — 1.24			1.10	1.26	1.47					1.68
10 — 3.45				1.05	1.39	1.07				4.17
14 — 2.06					1.56	1.36	1.15	1.04	0.94	1.32
18 — 3.30				1.17	1.44					2.49
22 — 4.57		0.91	1.04	1.19	1.39	1.07	0.87	0.74		3.30
23 — 5.16		0.82	0.98	1.16	1.43					3.99
24 — 6.02				1.25	1.36	1.12				5.79
27 — 4.75			1.07	1.23	1.36	1.18	0.95			3.81
30 — 3.81		0.96	1.09	1.24	1.36					3.63
Means		0.90	0.97	1.18	1.42	1.13	0.92	0.75	(0.94)	
Departures		+0.09	+0.02	+0.01		±0.00	−0.02	−0.06	−0.23	

MADISON, WIS.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Mar. 1 — 1.96		1.09	1.22	1.35	1.48	1.28				1.12
5 — 0.53			1.27	1.42	1.60					0.48
6 — 0.36			1.15							0.46
13 — 1.45				1.58	1.34	1.14				1.88
17 — 1.68			1.18	1.33	1.49	1.25	1.02			2.49
20 — 3.15				1.22		1.23				3.63
27 — 3.99						1.04				5.79
30 — 4.95				1.21						4.75
Means		(1.09)	1.20	1.31	1.54	1.23	(1.08)			
Departures		+0.03	±0.00	−0.02		−0.11	−0.10			

LINCOLN, NEBR.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Mar. 2 — 3.63			1.02	1.25						4.95
4 — 0.91			1.23	1.34	1.46					1.37
8 — 2.49						1.26	1.07	0.88	0.77	2.74
9 — 3.45		0.85	1.03	1.19	1.36					3.99
12 — 2.36						1.35	1.07	0.99		3.30
16 — 2.36	0.89	1.07	1.17	1.34			1.05	0.94	0.82	3.00
20 — 3.81	0.86	0.96			1.49	1.28	1.10	0.99	0.83	3.99
21 — 3.45			0.86	1.01	1.18	1.39	1.24			3.99
22 — 3.45			0.95	1.06		1.32				3.81
26 — 4.17			1.00	1.23	1.51	1.24	1.04	0.88	0.73	3.63
27 — 6.27		0.90	1.05	1.27						4.95
29 — 3.81				1.34						3.15
30 — 3.81			0.92	1.23	1.46	1.29	1.11	0.94	0.84	2.62
31 — 5.36			0.89	1.05	1.24	1.46				6.27
Means	(0.88)	0.93	1.05	1.26	1.43	1.28	1.07	0.94	0.80	
Departures	−0.04	+0.01	−0.04	−0.04		+0.01	−0.02	−0.01	−0.01	

SANTA FE, N. MEX.

Date (8 a.m. e.)	5.0	4.0	3.0	2.0	1.0*	2.0	3.0	4.0	5.0	Noon e.
Mar. 8 — 2.36			1.26					1.01	0.90	2.16
9 — 2.36				1.22						3.30
12 — 2.06				1.46						2.62
15 — 2.62					1.60	1.42	1.25	1.13		2.16
18 — 1.88			1.33		1.68		1.27	1.18	1.10	2.49
19 — 2.16			1.37	1.48	1.64	1.46	1.33	1.20	1.11	1.78
20 — 1.96		1.24	1.30	1.48		1.39	1.27	1.18	1.07	1.78
Means		(1.24)	1.32	1.41	1.64	1.42	1.28	1.14	1.04	
Departures		+0.04	±0.00	−0.04		+0.03	+0.03	+0.04	+0.01	

*Extrapolated.

TABLE 1.—*Solar radiation intensities during April, 1920*—Continued.

WASHINGTON, D. C.

Date.	8 a.m. 75th meridian time. e.	77.8° 5.0	75.7° 4.0	70.7° 3.0	60.0° 2.0	0.0° 1.0*	60.0° 2.0	70.7° 3.0	75.7° 4.0	77.8° 5.0	Noon Local mean solar time. e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 3	3.30		1.02	1.15	1.30	1.49					2.74
6	1.78				1.20						1.96
10	2.28					1.43					2.49
13	5.16				1.07						3.15
21	9.47					1.44	1.29	1.03			10.59
22	7.29		0.76	0.91							5.79
29	6.76			0.99	1.18	1.41	1.17				4.17
Means			(0.89)	1.02	1.19	1.44	(1.23)	(1.03)			
Departures			+0.14	+0.15	+0.13	+0.06	+0.14	+0.11			

MADISON, WIS.

Apr. 3	1.24				1.29						2.26
8	1.78				1.22	1.42					2.16
9	2.62				1.25						2.87
13	1.96				1.31	1.50					3.15
14	2.49				1.24						2.49
17	3.99				1.15						4.37
24	4.17					1.45	0.98				5.16
Means					1.24	1.46	(0.98)				
Departures					±0.00	+0.06	-0.27				

LINCOLN, NEBR.

Apr. 2			1.09	1.23	1.40						
9			0.61	0.79	1.01						
13			0.76	0.88	1.08						
20			0.81	0.93	1.14	1.40					
21				0.93	1.15	1.44	1.06	0.84	0.60	0.46	
27			0.95	1.08	1.30	1.59					
28				0.95	1.24	1.50					
Means			0.84	0.97	1.19	1.49	(1.06)	(0.84)	(0.60)	(0.46)	
Departures			+0.01	-0.04	-0.04	±0.00	-0.10	-0.14	-0.23	-0.25	

* Extrapolated.

Table 2 gives the average daily solar and sky radiation received on a horizontal surface for each weekly period from January 1 to April 29, 1920, inclusive. The period from February 26 to March 4 in 1920 contains 8 days. The weekly means of the departures of the daily values from normal values, and also the excess or deficiency of radiation since the first of the year, are also given. All three stations show a marked deficiency of radiation from about January 15 to February 25, and an excess during the first half of April.

During the months January to April, 1920, fewer skylight polarization measurements than usual were obtained at Washington and Madison, as the ground was frequently entirely or partly covered with snow. The measurements show about the average percentage of polarized light.

TABLE 2.

Week beginning—	Average daily radiation. Washington.	Madison.	Lincoln.	Average daily departure for the week. Washington.	Madison.	Lincoln.	Excess or deficiency since first of year. Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	189	156	134	27	11	- 54	188	80	- 375
8	156	184	209	- 11	29	7	109	281	- 326
15	135	154	219	- 41	-18	0	- 176	158	- 323
22	113	179	200	- 77	-13	- 35	- 717	66	- 571
29	189	176	107	- 17	-32	-145	- 839	- 160	-1,584
Feb. 5	197	156	235	- 30	-70	- 34	-1,051	- 648	-1,820
12	276	249	334	26	2	44	- 871	- 631	-1,513
19	187	251	153	- 82	-15	-161	-1,446	- 735	-2,638
26	355	307	387	66	15	44	- 922	- 618	-2,287
Mar. 5	340	372	419	29	52	44	- 720	- 256	-1,976
12	314	341	427	- 20	1	26	- 860	- 249	-1,794
19	410	276	396	61	-82	- 20	- 433	- 820	-1,933
26	363	342	450	- 4	-30	31	- 460	-1,028	-1,715
Apr. 2	397	468	488	10	82	73	- 393	- 455	-1,204
9	594	422	443	189	25	40	932	- 281	- 924
16	382	336	248	- 45	-78	-161	619	- 829	-2,053
23	436	343	391	13	-93	- 40	526	-1,476	-2,336

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, May 19, 1920.]

In continuation of preceding publications, I give in the following table the results obtained at Calama, Chile, in March, 1920, for the solar constant of radiation. The reader is referred to this REVIEW for February (pp. 85–87), August (pp. 580–582), and September (pp. 658–659), 1919, for statements of the arrangement and meaning of the table.

During the month of March only three days were lost to observation. This is very fortunate, for the month has been extremely interesting, owing to the remarkable solar phenomena centering about March 22. As shown in the following table of five-day mean values of the solar constant of radiation for the period beginning June 1, 1919, the broad features of the march of solar radiation values have been unusually interesting. In each month I have indicated the successive five-day periods by the capital letters A, B, C, D, E, and F. The last pentad includes all the days from the 26th to the end of the month. The values given are the number of thousandths of a calorie by which the solar radiation of a given time interval exceeds 1.900. Thus, for the first period of June the mean value is 1.946.

Approximate five-day mean solar-radiation observations.

	A.	B.	C.	D.	E.	F.[1]
1919.						
June	46	84	37	39	71	53
July	36	54	47	63	57	31
August	53	54	38	36	51	45
September	28	33	30	42	31	30
October	[3]18	[3]57	49	46	59	62
November	60	51	60	43	47	54
December	55	48	54	60	67	81
1920.						
January	69	102(?)	74	78	81	70
February		87	60	78	77	68
March	77	65	70	50	10	59

[1] Means for all the days from the 26th to the end of the month.
[2] Means for the 2d and 7th.
[3] Mean for the 8th, 9th, and 10th.

Up until the 7th of October there was, on the whole, a steady decline which had at last brought the observed values below the value 1.933 calories per square centimeter per minute representing the mean of the observations from 1903 to 1912, published in Volume III of the Annals of the Astrophysical Observatory. The concluding value of this series, taken October 7, is very strong since it depends upon a mean of four well-agreeing observations—three by the new method and one by the old. That value was 1.891. The value for the next following day, October 8, the mean of three well-agreeing observations by the new method, is 1.963. From this time until the middle of December, the values continued at the high average of 1.954. Then occurred a further rise to abnormally high averages; and for almost three months, from December 22 to March 17, the average value was about 1.976. There has not been so long-continued a period of high values during the time when the solar constant has been observed by the Smithsonian Institution, from 1905 until now.

Then occurred the remarkable, well-delineated large depression shown by the following values and having its minimum on March 23, only a few hours after the maximum activity of the sun, revealed by the great sun spots, aurorae, and the terrestrial magnetic disturbances of March 22 and 23. It is interesting to state in anticipa-